WENDELL

Relative Strength of Sandstone and Limestone Concrete

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RELATIVE STRENGTH OF SANDSTONE AND LIMESTONE CONCRETE

BY

FRANCIS GEORGE WENDELL

THESIS FOR DEGREE OF BACHELOR OF SCIENCE

IN CIVIL ENGINEERING

COLLEGE OF ENGINEERING

UNIVERSITY OF ILLINOIS

PRESENTED JUNE 1902

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IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE

OF Bachelor of Science in Civil Engineering

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Introduction.

Engineers often desire to know the relative strength of concretes having different aggregates. Unfortunately most of the results at hand do not give enough data to intelegently interpret their meaning. It has been the object in making this set of experiments, to determine the relative crushing strength of concrete cubes made with sandstone in one case and limestone in the other.

The experiments consisted of making and crushing about seventy-five 6-inch cubes. These cubes were all made with the same proportion of ingredients and were tested at the following ages: seven, fourteen, and twenty-one days, and one, two, three, four, and five months. Each set of experiments consisted in crushing eight cubes. As will be seen by reference to the data sheets, the time of making these cubes was not according to any particular plan, owing to the uncertainty of the testing machine's being in place at any particular date.

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Introduction

The purpose of this thesis is to discuss the relation-ship of [illegible] having different [illegible] [illegible] [illegible] of the [illegible] at [illegible] [illegible] [illegible] [illegible] [illegible]. [illegible] [illegible] [illegible] of [illegible] [illegible] [illegible] [illegible] of [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible].

The [illegible] [illegible] of [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] of [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] of [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] of [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] of [illegible] according to the [illegible] of the [illegible] [illegible] [illegible] [illegible] [illegible]

Materials.

WATER. The water used in connection with the experiments was taken directly from the mains of the University water works, the supply being obtained from two wells about 150 feet deep. The temperature of the water was taken at various times, and was found to vary from 49° to 53° Farenheit.

SAND. The sand used in the cubes numbered from 1 to 36 inclusive was a fine drift sand obtained from the banks east of Urbana, Illinois. The fineness is given in Table 1.

TABLE 1. FINENESS OF SAND NO 1.

Caught on No 6	4.9 percent
Passed No 6 and left on No 20	38.2 PerCent
Passed No 20 and left on No 30	13.9 PerCent
Passed No 30	43.0 PerCent
Total	100.0 PerCent

The sand used in cubes numbered from 37 to 74 inclusive was more uniform but somewhat coarser, than the first. Table 2

gives the fineness of the second lot.

TABLE 2. FINENESS OF SAND NO 2.

Caught on No 6	1.9 Per Cent
Passed No 6 and left on No 20	70.0 " "
Passed No 20 and left on No 30	8.9 " "
Passed No 30	19.2 " "
Total	100.0 " "

One cubic foot of sand No 1, dropped from a height of three feet weighed 99 pounds, and had 30 per cent of voids; and one cubic foot of sand No 2, dropped from the same height, weighed 100 pounds, the voids not being determined.

STONE. The limestone used was obtained from Kankakee, Illinois, and is usually called Kankakee Limestone. It has a crushing strength of about 11650 pounds per square inch (average of 15 tests)*. One cubic foot of crushed stone weighed 80 pounds and contained 38 per cent of voids when rammed. The per cent passing the different screens is given in Table 3.

*J. G. Mosier's Bachlor's Thesis, University of Illinois.

TABLE 3. FINENESS OF LIMESTONE.

Left on the 1" Screen	46. percent
Passed the 1" and left on ½" Screen	51. " "
Passed the ½" Screen	3. " "
Total	100. " "

The sandstone was quarried at Williamsport, Indiana, and is known indifferently as "Riverside", Williamsport or Independence sandstone. It has a crushing strength of about 6250 pounds per square inch (average of 4 tests)* The broken sandstone weighed 80 pounds per cubic foot, and contained 36 per cent of voids when rammed. The fineness is given in Table 4.

TABLE 4. FINENESS OF SANDSTONE.

LEft on the 1" Screen	50. PerCent
Passed the 1" and left on ½" Screen	43. "
Passed the ½" screen	7. "
Total	100. "

CEMENT The cement selected was

*20th annual report of the Indiana State Geologist.

Atlas American Portland. The following data was obtained direct from the company's New York office.

"The stone used in the manufacture of Atlas Portland Cement is what is known as silicious limestone, obtained from the quarries located at Northampton, Pa. The material is burned in a powdered form and is reground after burning to a fineness of 95 per cent passing the No 100 sieve and 75 per cent passing the No 200 sieve. The burning is done under the rotary cylinder process and the fuel employed is powdered coal."

The weight of one cubic foot of this cement dropped from a sieve 3 feet above the measuring box was found to be 74 pounds.

It is thought unnecessary to give more specific information concerning the cement as comparative results were what was wanted, and cement from the same barrel was used throughout the entire set of experiments.

The Proportions.

An attempt was made in the first 36 cubes to determine the proportions with reference to voids. In order to determine the proportions by this method it is first necessary to have the per cent of voids in the rammed aggregate. The voids in the rammed limestone were determined by filling a small pail with broken stone in successive layers about 2 inches thick, ramming each layer thoroughly before putting in the next. The pail was then filled with water and allowed to stand for a fiew minutes until it was thought, by the disappearance of bubbles, that little absorption was taking place. Water was then added until it just covered the stone and then immediately poured off and measured. The obvious ratio gives the per cent of voids.

In the case of the sandstone the material was so soft that when rammed it crumbled and almost filled the intrices between the stones, so

another method for determining the per cent of voids had to be used. The method devised was to determine the voids in the loose sandstone and limestone by the method just described except, that neither was rammed. Having the relative per cent of voids in the loose aggregates and the per cent of voids in the rammed limestone, the true per cent of voids in the rammed sandstone was calculated as follows:

Sandstone not rammed	=	39.9	per cent voids
Limestone " "	=	42.0	" " "
" rammed	=	38.0	" " "
Sandstone "	=	X	" " "

Then by proportion

38 : 42 :: X : 39.9

Whence X = 36.1 per cent voids

The proportion of voids in the sand was determined by filling a vessel with sand and compacting it by ramming, then determining the amount of water that could be put into the vessel with the sand. This quantity of water divided by the amount

of water alone which the vessel contained gave the proportion of voids. Some difficulty was met with in getting the water to fill the intrices between the grains of the rammed sand on account of the air bubbles remaining in the sand. This was obviated by ramming the sand in thin layers and then pouring in enough water to fill the voids after each layer was thoroughly rammed.

The details of the method of determining the proper amounts of cement, sand and stone are as follows: The rammed limestone contained 38 per cent voids, and the assumption was made that the mortar should equal 140 per cent of the voids (see Table 13c, page 112 b of Baker's Masonry Construction). The stone compacted 4 per cent in ramming; and therefore a yard of loose stone would be equal to 0.96 of a yard of the rammed stone. adding mortar equal to 140 per cent of the voids increases the volume to about 114 per cent. (Table 13c of Baker's

Masonry Construction); and therefore adding the mortar increased the volume of the rammed aggregate to 0.96 x 1.14 or 1.09 cu. yd., which is the volume of the concrete produced by a yard of loose aggregate. To produce a yard of concrete therefore required 1 ÷ 1.09 or 0.92 cu. yd. of loose stone. Since the mortar equaled 140 per cent of the voids, a yard of concrete would require 1.40 x .38 or 0.53 cu. yd. of mortar. The rammed sand contained 30 per cent of voids; and therefore to fill the voids of the sand with cement paste required 30 per cent as much packed cement as loose sand; or the proportions of the mortar required was about 1 volume of packed cement to 3½ volumes of loose sand. Interpolating from Table 11 of Baker's Masonry Construction, we find that to produce a yard of this mortar requires 1.87 bbl. of Portland Cement and 0.86 cu. yd. of sand. Therefore a yard of concrete requires 0.53 x 1.87, or 0.99 bbl, or 0.128 cu. yd. of Portland cement; and

0.53 × 0.86 or 0.46 cu. yd. of sand. The
The quantities for a cu. yd. of rammed concrete were therefore 0.128 cu. yd. of packed cement, 0.46 cu. yd. of loose sand and 0.92 cu. yd. of loose broken stone. The proportions were: 1 volume of packed cement, $3\frac{1}{2}$ volumes of loose sand, and 7.3 volumes of loose broken stone.

By exactly the same method, the proportions for the sandstone were determined. Rammed sandstone contained 36 per cent voids, sandstone compacted 4 per cent in ramming, and rammed sand contained 30 per cent of voids. The proportions were found to be: 1 volume packed cement, $3\frac{1}{2}$ volumes loose sand and 7.6 volumes of stone.

The proportions of 1 : 3.5 : 7.3 were selected for both sandstone and limestone cubes. It was thought more convenient to make all the measurements of the ingredients, except water, by weight; and hence the proportions by volume were reduced to proportions

by weight.

The method used to reduce the proportions by volume to proportions by weight is as follows:

Weight of cement to fill a box		= 3680 gr.
" " sand " " same "		= 4960 "
" " stone " " " "		= 3980 "

Proportions by volume are 1 : 3½ : 7.3

Relative weights per unit volume 3680 : 4960 : 3980

Proportions by weight 3680 : 17360 : 29054

" " " 1 : 4.7 : 7.9

The following is the quantity of material used for 2, 3 and 4 cubes respectively, which in each case gave a slight excess over the amount needed to fill the molds.

Material for 2 cubes:

Stone, 10500 grammes

Cement, 1329 "

Sand, 6246 "

Material for 3 cubes:

Stone, 15750 grammes

Cement, 1994 "

Sand, 9369 "

Material for 4 cubes:

Stone, 21000 grammes

Cement, 2658 grammes
Sand, 12492 "

The amount of water used in each case was $12\frac{1}{2}$ per cent of the total weight of the sand and cement.

Apparatus.

MOLDS. The molds were made of 2-inch oak in three compartments and were made as to be easily taken apart. The boards forming the sides were groined, so as to recieve the four 2-inch partitions. The sides were held against the ends of the partitions by four half-inch bolts, which bolts were removed each time the mold was torn down. The molds were placed directly on the slate slab of the mixing table so that the slab formed the bottom of the molds. Four such molds were used.

Making Cubes.

WEIGHING. All of the materials except

the cement and water were weighed on a pair of small platform scales. The same bucket for holding the materials was used throughout the experiments and as the scales were provided with a double beam the bucket was counter-balanced on the pound-beam. By this means the net weight of the materials could be read directly from the other beam. The cement was weighed in a small tin pan on an ordinary pair of balances. All weights were recorded in grams The water was measured in a 500 c.c. graduate.

MIXING. The sand and cement were first put on a slate table and mixed with a trowel until the mixture had a uniform color. The water was then added and the mass thoroughly mixed with a trowel for about 5 minutes, and then spread uniformly over the slate slab. A wooden frame made of 6-inch boards was then placed around the table and the stone added. To prevent the dry stone absorbing water from the mortar, the desired

quantity of stone for a batch was always dipped in water, to wet the surface, and the water allowed to immediately run off. The instrument used to do the final mixing was a small square hoe, this was run through the ingredients in a plow-like manner, the materials being turned and mixed from one end of the box to the other. This operation required on the average about 7 minutes, depending somewhat on the amount of material that was being mixed.

MOLDING. The material was taken from the table with a trowel and deposited in the molds in successive layers about 2 inches thick, each layer being thoroughly rammed before the next was applied. The top of each cube was left as smooth as was possible with the tamper, which had a 3-inch square base and weighed 11 pounds. The tamping was usually continued until moisture appeared on the top of the finished cube.

After the tamping of a batch was completed a small ammount of cement mortar was put on the top of each cube

and smoothed over with a trowel. The next day the cubes were numbered on this neat cement with a steel stamp all sandstone cubes stamped with consecutive odd numbers and limestone with even numbers. An even number of cubes varying from 4 to 12 was always made each time so that the cubes always went in pairs - a sandstone with a limestone.

STORING. The cubes were in all cases left in the molds for 24 hours, and at the end of that time the molds were torn down and the cubes set on the floor of the laboratory to season. At the end of from 1 day to 2 weeks the cubes were removed from the laboratory floor and placed in tanks under water and allowed to remain there until about 1 hour before testing. The temperature of the water in the tanks varied from 36° to 56° F, which may have caused a variation in the strength of the cubes.

TESTING. The cubes were tested, the most of them on an Olsen 200,000-pound

testing machine, but a few of them were tested on a 100000-pound machine manufactured by the Philadelphia Machine and Tool Company. The top and bottom of the cubes were selected as the bearing surfaces and therefore the pressure was always applied in a direction parallel to the direction of the tamping. As the tamper had a tamping area of only 9 square inches, it was almost impossible to get smooth, parallel surfaces on the top and bottom of the cubes, but this was taken care of by a ball and socket compression block. The cube was placed on the platform of the testing machine with the compression block just above it, and the movable compression plate lowered so as to come in contact with the top of the block.

The cubes first showed signs of yielding by the appearance of small vertical cracks. It was noticed that soon after the cubes failed, but in no case before, small

pieces of concrete would begin to fall out of the sides and this continued as the pressure increased until, in most cases, two pyramids having their apexes together and their bases on the plates, were left.

Discussion.

DETERMINATION OF VOIDS IN SANDSTONE.

The method of determining the voids in the sandstone may be criticized on the ground that the stone would crumble when the concrete was being rammed, and produce a smaller per cent of voids, the same as it did before the mortar was added. This may be true to a certain extent, but the mortar forms a cushion and tends to lessen the force of each blow. If any of the fragments crumble on being rammed, it is a fault of the stone and not of the method of determining the per cent of voids.

It was thought that more uniform results could be obtained by determining the per cent of voids in the stone,

and then using just enough mortar to fill them. If an excess of mortar is used, there is a constant tendency to do too little mixing.

BEARING SURFACES. It was thought best to apply the pressure on the cubes parallel to the direction of tamping, for two reasons: First, in practice the pressure is almost always applied in this way; and second, in case some of the tamped layers were not exactly horrizontal there would be no tendency to shear between the successive layers.

Results.

As stated before, the object of making this set of experiments was to determine the relative strength of two concretes having different aggregates. Owing to the many variable factors, it was not expected that a definite mathematical ratio could be established between the two concretes. By reference to the data sheets,

(pages 26 to 33 inclusive) it will be seen that some of the individual results have been rejected, in order to have 8 cubes in each each set of experiments.

From a study of the diagram (page 24) several interesting results are noted.

1. It will be seen by the diagram refered to, that the cubes tested at the end of one week are stronger than those tested at the end of two weeks. This is undoubtedly due to the fact that the first were put into water when one day old, (see Data Sheet 1, page 26) while those tested at the end of two weeks remained four days in air. This certainly proves the statement that concrete in order to get maximum strength should be put into water as soon as the cement has had time to set. Varying the length of time between making and immercing has undoubtedly influenced the remainder of the experiments somewhat, but not to so great an extent with the longer-time tests.

2. Data Sheets 4 and 5 (pages 29 and 30) show that the sand was changed after the one-month cubes were made, and as a result

the two-month cubes are no stronger than the one-month cubes. Sand No. 2 was used in the shorter tests which goes to show that uniform coarse sand makes stronger concrete than uniform fine sand.

3. On page 24 has been plotted a curve showing the probable error of the different experiments. The data for the probable error curve was computed from the following well known formula for the probable error of the mean of several observations.

$$E_m = .6745\sqrt{\frac{\Sigma d^2}{(n-1)n}}$$

where E_m = the probable error of the mean of all the observations.

d = the difference between any observation and the mean of all the observations.

n = the number of observations.

Σ = symbol signifying sum of.

This curve shows that the probable error of the results varied about as the length of the test. This proves that the shorter the test the more uniform the results. This result might naturally

be expected, because in the longer tests any irregularities in the mixing and tamping deviate more and more as the cement hardens.

4. From a study of the cubes tested it was noticed that in the two-, three-, four-, and five-month tests some of the grains of sand were broken, both in the sandstone and limestone cubes. It was also noticed that in the one-, and two-weeks tests of sandstone cubes, and in the one-, two-, three-, and four-weeks tests of the limestone cubes some of the stones projected out above the plane of fracture, which goes to show that the adhesion of the mortar was not as great as the strength of the stone. In the remainder of the tests all of the stones were broken along the plane of rupture.

The grains of sand in cubes containing sand No 1, did not seem to adhere to each other as did the grains in cubes containing the coarser sand. The surface of fracture of the cubes containing the fine sand was

of a mealy nature and when the hand was rubbed lightly over the plane of rupture, some of the grains would fall out. This showed that not enough cement was used for this particular sand, and as a result did not give a strong concrete.

5. On page 25 has been plotted a curve showing the varying ratios of the strength of the limestone to that of the sandstone cubes for different length of tests. Owing to the different conditions under which the cubes were made, this curve varies much more than a theoretical curve.

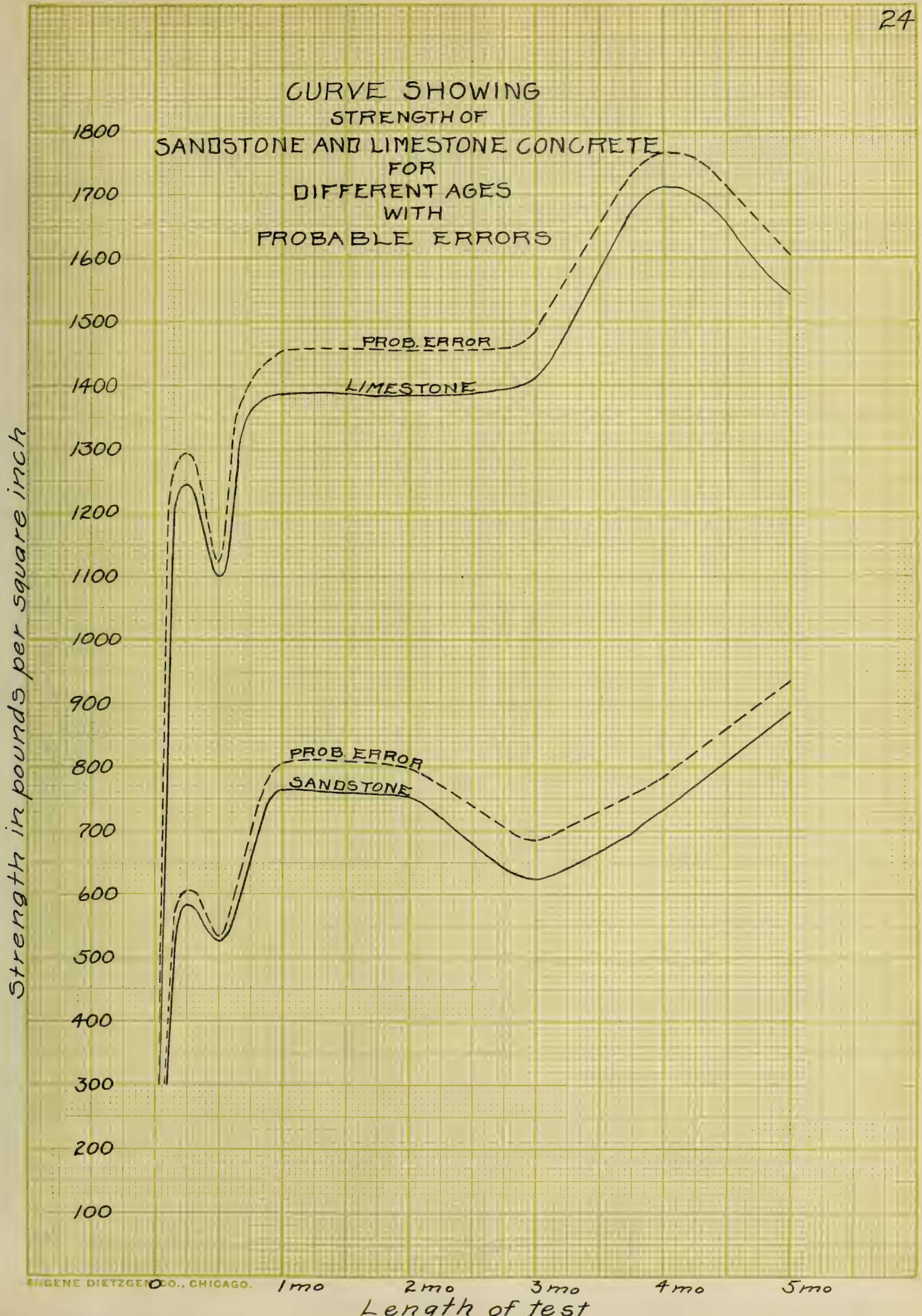
When the cubes were first made the crushing strength of all was, of course the same, but as the cement gained strength there was more and more adhesion of the mortar to the stone. This was shown by the fact that up to and including the one-month tests, the amount of limestone broken along the plane of rupture varied with the age of the cubes; and the same was true of the sandstone cubes up to and including the two-weeks tests.

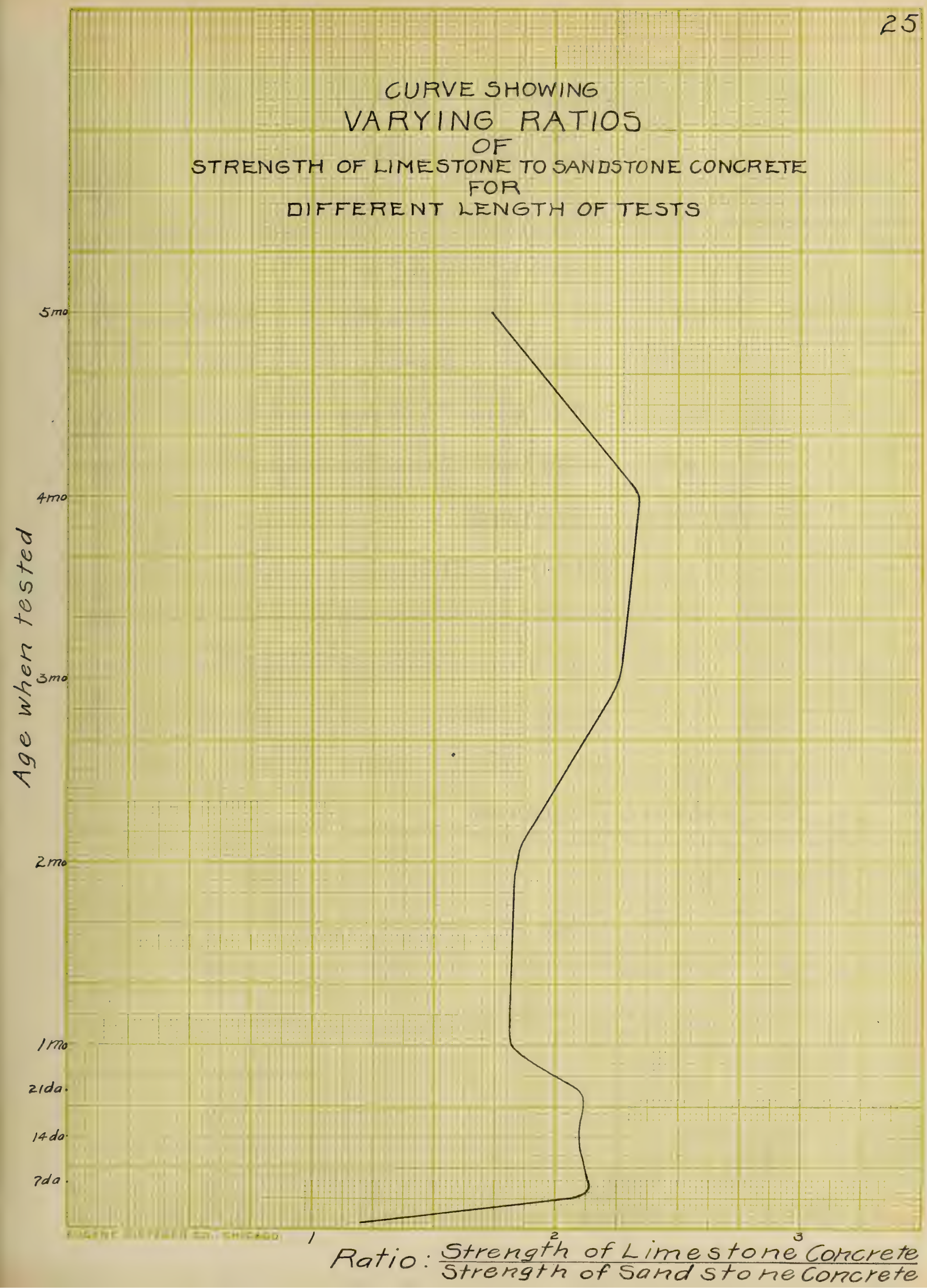
Therefore, theoretically, a constant increasing ratio should exist between the strength of the limestone and sandstone cubes up to and including the fourteen-day tests, while the twenty-one and twenty-eight day tests should show a still greater constant increasing ratio. A constant ratio should exist between the two-, three-, four-, and five-month limestone and sandstone cubes because all the aggregate was broken.

6. Several interesting results might be deduced from the data sheets and curves, other than those mentioned; but it is thought that those which may be of the most use, have been pointed out.

Conclusions.

It seems safe to say, that if care is taken, a Kankakee-limestone concrete can be made about twice as strong as one composed of the sandstone used in these experiments.


CURVE SHOWING
STRENGTH OF
SANDSTONE AND LIMESTONE CONCRETE
FOR
DIFFERENT AGES
WITH
PROBABLE ERRORS
PROB. ERROR
LIMESTONE
PROB. ERROR
SANDSTONE
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
Strength in pounds per square inch
0
1 mo
2 mo
3 mo
4 mo
5 mo
Length of test
EUGENE DIETZGEN CO., CHICAGO.


CURVE SHOWING
VARYING RATIOS
OF
STRENGTH OF LIMESTONE TO SANDSTONE CONCRETE
FOR
DIFFERENT LENGTH OF TESTS
Age when tested
5mo
4mo
3mo
2mo
1mo
21da.
14da.
7da.
1
2
3
Ratio: Strength of Limestone Concrete / Strength of Sandstone Concrete

DATA SHEET I.

7-DAY TESTS

No of Cube	Date of Making	Date of Breaking	Date of Immercing	Crushing Strength Total	Crushing Strength lbs per □"	Sand No	Testing Machine Used
			SANDSTONE				
67	2-26-02	3-5-02	2-27-02	19700	547	2	Olsen 200,000.
69	2-26-02	3-5-02	2-27-02	24000	667	2	"
71	2-26-02	3-5-02	2-27-02	21600	600	2	"
73	2-26-02	3-5-02	2-27-02	18800	522	2	"
				Average	584±22		
			LIMESTONE				
68	2-26-02	3-5-02	2-27-02	37400	1039	2	"
70	2-26-02	3-5-02	2-27-02	49500	1375	2	"
72	2-26-02	3-5-02	2-27-02	45200	1252	2	"
74	2-26-02	3-5-02	2-27-02	47100	1308	2	"
				Average	1244±50		

Average strength of Lime stone Concrete in terms of that of the Sandstone. 2.13

DATA SHEET 2
14-DAY TESTS

No of Cube	Date of Making	Date of Breaking	Date of Immercing	Crushing Strength Total	Crushing Strength lbs per □"	Sand No	Testing Machine Used
			SANDSTONE				
55	2-8-02	2-22-02	2-12-02	19900	553	2	Olsen 200,000
57	2-8-02	2-22-02	2-12-02	18700	519	2	"
59	2-8-02	2-22-02	2-12-02	19000	528	2	"
61	2-8-02	2-22-02	2-12-02	18100	503	2	"
63	2-8-02	2-22-02	2-12-02	26700	742*	2	"
				Average	525±7		
			LIMESTONE				
56	2-8-02	2-22-02	2-12-02	36500	1014	2	"
58	2-8-02	2-22-02	2-12-02	38000	1056	2	"
60	2-8-02	2-22-02	2-12-02	41000	1139	2	"
62	2-8-02	2-22-02	2-12-02	42900	1192	2	"
64	2-8-02	2-22-02	2-12-02	32100	892*	2	"
				Average	1100±21		

Average strength of Limestone Concrete in terms of that of the Sandstone 2.10

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*Omitted from average.

DATA SHEET 3
21-DAY TESTS

No of Cube	Date of Making	Date of Breaking	Date of Immercing	Crushing Strength Total	Crushing Strength lbs per □"	Sand No	Testing Machine Used
			SANDSTONE				
47	2-7-02	2-28-02	2-11-02	24300	675	2	Olsen 200,000.
49	2-7-02	2-28-02	2-11-02	20600	572	2	"
51	2-7-02	2-28-02	2-11-02	25000	694	2	"
53	2-7-02	2-28-02	2-11-02	23300	647	2	"
65	2-8-02	3-1-02	2-12-02	19700	547 *	2	"
				Average	647±22		
			LIMESTONE				
48	2-7-02	2-28-02	2-11-02	46900	1303	2	"
50	2-7-02	2-28-02	2-11-02	48600	1350	2	"
52	2-7-02	2-28-02	2-11-02	44500	1236	2	"
54	2-7-02	2-28-02	2-11-02	56000	1555	2	"
66	2-8-02	3-1-02	2-12-02	45400	1261*	2	"
				Average	1360±46		"

Average strength of Limestone Concrete in terms of that of the Sandstone 2.10

*Omitted from average.

DATA SHEET 4
1-MONTH TESTS

No of Cube	Date of Making	Date of Breaking	Date of Immercing	Crushing Strength Total	Crushing Strength lbs per □"	Sand No	Testing Machine Used
			SANDSTONE				
37	2-6-02	3-6-02	2-11-02	28160	782	2	Philadelphia Machine
39	2-6-02	3-6-02	2-11-02	32480	902	2	"
41	2-6-02	3-6-02	2-11-02	27370	760	2	"
43	2-7-02	3-7-02	2-11-02	28400	788	2	"
45	2-7-02	3-7-02	2-11-02	21990	610	2	"
				Average	765±40		
			LIMESTONE				
38	2-6-02	3-6-02	2-11-02	48220	1339	2	"
40	2-6-02	3-6-02	2-11-02	49980	1388	2	"
42	2-6-02	3-6-02	2-11-02	57570	1599	2	"
44	2-7-02	3-7-02	2-11-02	40500	1125	2	"
46	2-7-02	3-7-02	2-11-02	51850	1440	2	"
				Average	1388±66		

Average strength of Limestone Concrete in terms of that of the Sandstone 1.82

*Omitted from average.

DATA SHEET 5
2-MONTH TESTS

No of Cube	Date of Making	Date of Breaking	Date of Immercing	Crushing Strength Total	Crushing Strength lbs per □"	Sand No	Testing Machine Used
			SANDSTONE				
29	12-14-01	2-18-02	12-18-01	25200	700	1	Olsen 200,000.
31	12-14-01	2-18-02	12-18-01	33820	939	1	"
33	12-14-01	2-21-02	12-18-01	22700	632	1	"
35	12-14-01	2-21-02	12-18-01	26700	742	1	"
				Average	753±44		
			LIMESTONE				
30	12-14-01	2-18-02	12-18-01	59000	1639	1	"
32	12-14-01	2-18-02	12-18-01	52000	1444	1	"
34	12-14-01	2-21-02	12-18-01	46000	1277	1	"
36	12-14-01	2-21-02	12-18-01	42400	1177	1	"
				Average	1384±68		

Average strength of Limestone Concrete in terms of that of the Sandstone 1.84

DATA SHEET 6

3-MONTH TESTS

No of Cube	Date of Making	Date of Breaking	Date of Immercing	Crushing Strength Total	Crushing Strength lbs per □"	Sand No	Testing Machine Used
			SANDSTONE				
21	12-11-01	3-11-02	12-18-01	13680	380	1	Philadelphia Machine
23	12-11-01	3-11-02	12-18-01	29000	805	1	"
25	12-11-01	3-11-02	12-18-01	26260	729	1	"
27	12-11-01	3-11-02	12-18-01	20880	580	1	"
				Average	623±63		
			LIMESTONE				
22	12-11-01	3-11-02	12-18-01	43660	1212	1	"
24	12-11-01	3-11-02	12-18-01	48210	1339	1	"
26	12-11-01	3-11-02	12-18-01	49290	1369	1	"
28	12-11-01	3-11-02	12-18-01	62170	1726	1	"
				Average	1411±74		

Average strength of Limestone Concrete in terms of that of the Sandstone. 2.26

DATA SHEET 7

4-MONTH TESTS

No of Cube	Date of Making	Date of Breaking	Date of Immercing	Crushing Strength Total	Crushing Strength lbs per □"	Sand No	Testing Machine Used
			SANDSTONE				
11	11-29-01	3-31-02	12-13-01	25200	700*	1	Olsen 200,000.
13	12-7-01	4-5-02	12-18-01	24950	693	1	"
15	12-7-01	4-5-02	12-18-01	20500	569	1	"
17	12-7-01	4-5-02	12-18-01	26900	747	1	"
19	12-7-01	4-5-02	12-18-01	33300	925	1	"
				Average	733±50		
			LIMESTONE				
12	11-29-01	3-31-02	12-13-01	69100	1919*	1	"
14	12-7-01	4-5-02	12-18-01	71100	1975	1	"
16	12-7-01	4-5-02	12-18-01	61550	1709	1	"
18	12-7-01	4-5-02	12-18-01	51900	1441	1	"
20	12-7-01	4-5-02	12-18-01	62300	1730	1	"
				Average	1713±53		

Average strength of Limestone Concrete in terms of that of the Sandstone 2.34

*Omitted from average.

DATA SHEET 8

5-MONTH TESTS

No of Cube	Date of Making	Date of Breaking	Date of Immercing	Crushing Strength Total	Crushing Strength lbs per □"	Sand No	Testing Machine Used
			SANDSTONE				
1	11-27-01	4-26-02	12-13-01	31300	869	1	Philadelphia Machine
3	11-27-01	4-26-02	12-13-01	26050	723	1	"
5	11-29-01	4-29-02	12-13-01	32000	888	1	"
7	11-29-01	4-29-02	12-13-01	38460	1068	1	"
9	11-29-01	4-29-02	12-13-01	20900	580*	1	"
				Average	887±48		
			LIMESTONE				
2	11-27-01	4-26-02	12-13-01	53730	1492	1	"
4	11-27-01	4-26-02	12-13-01	57520	1597	1	"
6	11-29-01	4-29-02	12-13-01	47910	1330	1	"
8	11-29-01	4-29-02	12-13-01	63200	1755	1	"
10	11-29-01	4-29-02	12-13-01	55900	1552*	1	"
				Average	1543±60		

Average strength of Limestone Concrete in terms of that of the Sandstone 1.74

*Omitted from average.

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